284

LIMITED CIRCULATION

This paper is not an official document. It is for information only and must not be quoted in any printed publication without prior permission of the author.

AGRICULTURAL MEMORANDUM No 1049

INVERSION MEASUREMENTS AT FRANSHAM, NORFOLK - J COCHRANE

Summary

Temperature profiles between 1.5 m and 15 m above ground in a pear orchard during spring 1983 and 1984 are described.

Some implications for the use of wind machines for low temperature protection are discussed.

Introduction

A preliminary analysis of profile measurement at Fransham in 1983 was given in Cochrane (1983). The measurements were repeated in 1984 using the same mast and temperature sensors. Observations at 20 or 15 minute intervals were logged using a Grant Squirrel SQ8 4-U data logger. The increased frequency of readings in 1984 allow an examination of more detail of the structure of these low level inversions.

Results and Discussion

Some details of the occasions when temperatures at 10 m and 15 m were greater than or equal to temperature at 1.5 m (referred to as inversions from now onwards) are given in Table 1. The "minimum" temperature is the lowest observed temerature at 1.5 m (hourly in 1983, every 20 minutes up to 8 May 1985 and every 15 minutes for the remaining period). The "maximum inversion" refers to the greatest difference between the 1.5 m temperature and that at 10 or 15 m and did not necessarily coincide with the minimum temperature.

1) Frequency of inversions: Inversion conditions occurred on 80 to 90% of occasions during the period of the study - 34 out of a possible 38 in 1983 and 32 out of a possible 40 in 1984. On virtually all occasions the inversion extended to 15 m.

   N.B. Comments on inversions to 15 m in Cochrane (1983) were in error - an instrument correction to the 15 m thermistor was, unfortunately, neglected.

2) Strength of inversions: Statistics of the inversion strength for the two years are shown in Table 2. The inversions in 1984 are significantly stronger both as maximum and mean values (t-test, $p < 0.001$). In the absence of detailed weather observations at Fransham, there is no clear reason for this difference although part of the answer may lie in the effects of soil moisture on the temperatures. April and May were very wet in 1983 (rainfall about twice normal in both months) while April and the first 3 weeks of May in 1984 were very dry.

   The different character of the two seasons is apparent also in the relative frequency of days of predominantly cyclonic and anticyclonic character. Table 3 shows the number of such days in 1983 and 1984 (Lamb 1983, 1984) compared with an average frequency over the 10-year period 1962-71 (Lamb 1972).

FH2B

For the purpose of this comparison, pure and mixed cyclonic and anticyclonic types have been counted together. Anticyclonic conditions are generally more favourable for inversion development and inversions on these occasions would probably be stronger than those occurring under cyclonic regimes.

3) Structure of inversion: Some details of typical temperature changes in the profile during the establishment and breakdown of inversions in April 1984 are presented in Figures 1 to 3. Some points of interest are discussed below with the aid of limited observation details from Marham.

i) 21-22 April (see Figure 1). After a fine warm afternoon at Marham with thin high cloud and winds of 10-15 knots from the south west, temperatures fell rapidly during the evening as winds became south easterly about 2 knots. Between 01 and 02 GMT the surface wind at Marham became northerly and increased to 7 to 10 knots from 03 GMT onwards. During this period the high cloud had been thickening slowly. The air was fairly dry - afternoon dew point depression about 17°C at maximum temperature (RH 30 to 35%) and remained comparatively dry (maximum RH 70 to 75%) even with the on-shore breeze after midnight.

Under these conditions, the inversion at Fransham formed in the early evening and strengthened rapidly to a maximum by about 21 GMT. The surface warming just before midnight has no apparent cause in the observations available from Marham, but is probably due to local turbulent eddies.

The sudden rise in temperature at 1.5 m at about 03 GMT, coupled with an increased rate of cooling at 10 and 15 m, appears to be associated with the onset of a northerly breeze of 7 to 10 knots at Marham. It is possible to speculate that the increased turbulence due to such a breeze would produce a temperature structure similar to that resulting from the use of a wind machine from about 0230 onwards.

The method of forecasting minimum temperature used at Marham would have indicated a minimum of about 6°C with very light winds or 8°C with winds of 7 to 10 knots (personal communication, Marham forecaster). The lower value is consistent with a continuation of the general rate of cooling between 2300 and 0300 to a minimum at about 0530 (half an hour after sunrise).

While the increased mixing did produce a near isothermal layer, it must be noted that, once the initial increase in surface temperature had been achieved, the whole layer continued to cool at a rate which, if anything, was slightly greater than the previous rate of surface cooling.

ii) 29-30 April (see Figure 2). At Marham another day of thin high cloud - this time tending to decrease during the night. Easterly winds of 15 knots during the afternoon decreased in the evening but remained 7 to 10 knots throughout the night. The air was dry with afternoon dew points as low as -3°C (RH 35 to 40%)and with overnight RH remaining below about 80%.

On this occasion the development of the inversion more closely followed the simplistic picture of surface temperature falling more quickly than those at higher levels to give a maximum inversion strength about the time of minimum temperature. The surface (1.5 m)

temperatures fell somewhat lower that might have been expected with wind speeds about 10 knots overnight; it is possible however that the reduction in wind speed caused by the orchard environment and other local shelter may have resulted in much lighter winds at Fransham than in the open exposure at Marham.

iii) 22-24 April (Figure 3). Cloud dispersed during the evening and early part of the night of 22 April to give a clear night. However comparatively moist air (afternoon dew point depression about 6°C, RH 65 to 70%) and surface winds maintaining 6 to 8 knots throughout the night (at Marham) prevented the minimum temperatures from falling much below 5°C. This, in turn, produced the relatively weak inversion of the morning of 23 April.

The following 24 hours were initially cloudless but maximum temperature on 23 April was held down to about 15°C at Marham - decreasing eastwards to only 10°C near the coast - under the influence of the 10 to 12 knot easterly winds. However the air was very dry with afternoon dew points as low as 1°C (RH about 40%) and with continuing clear skies and winds decreasing to about 5 knots, minimum temperatures fell to around 2°C, resulting in the rather stronger inversion of the morning of 24 April.

4) Some implications for wind machines: It is clear, even from the limited measurements made so far, that these low level inversions have a complex structure. The maximum inversion value does not necessarily coincide with the minimum surface temperature nor is there a steady increase in the strength of the inversion as surface cooling takes place.

As suggested in Barrowcliffe (1984), a number of processes of differing scales in both time and space, both within and outside the boundary layer, operate to disturb the relative rates of cooling at different levels. The claim that a wind machine can raise tree-height temperature by half the value of inversion from 1.5 m to 10 m appears to be tied to an over-simplistic picture of the structure and development of the inversion - especially as no definition of "inversion value" is given.

It is hoped that further measurements made in "protected" and "un-protected" areas of the orchard during continuous and intermittent operation of the wind machine may throw more light on the way in which the inversion profile may be affected by such a device.

Acknowledgement

Grateful thanks are due to Robert Salmon, Hyde Hall, Fransham for his continued assistance and provision of facilities in this study of low level inversions.

April 1985

Agrometeorlogy Department
ADAS, Cambridge

References

Cochrane, J. 1983. "Wind machines for Frost Protection". Agricultural Memorandum No. 996.

Barrowcliffe, R. 1984. "The Nocturnal Boundary Layer with reference to the use of wind machines for Frost Protection". Agricultural Memorandum No. 1036.

Lamb, H. H. 1983. Climate Monitor, 12, 1 and 2, pp 84, Climatic Research Unit, University of East Anglia.

Lamb, H. H. 1984. Climate Monitor 13, 2, pp 53.

Lamb, H. H. 1972. British Isles Weather Types and a Register of the daily sequence of Circulation Patterns 1861-1971. Meteorological Office Geophysical Memoir No. 116, HMSO.

Table 1a

Inversions in 1983 (22 April to 31 May)

Night ending	'Minimum' Temperature	Inversions 10 m Max	10 m Mean	10 m Hours	15 m Max	15 m Mean	15 m Hours
24 Apr	1.7	0.0	0.0	1	)		
26 "	2.5	1.9	0.9	8	)		
27 "	3.3	0.6	0.1	8	) No records		
29 "	2.5	1.4	0.7	6	)		
30 "	1.7	1.9	1.1	6	)		
3 May	5.3	0.3	0.0+	15	0.3	0.0+	10
4 "	1.9	1.7	0.4	20	2.0	0.6	13
5 "	4.4	0.5	0.1	13	0.4	0.2	9
6 "	8.6	0.3	0.1	16	0.4	0.2	6
7 "	8.6	1.7	0.6	14	2.0	0.7	12
8 "	8.0	0.6	0.2	17	0.6	0.3	10
9 "	5.5	1.1	0.3	13	1.5	0.7	9
10 "	1.7	0.6	0.2	18	0.6	0.4	11
11 "	3.0	0.6	0.3	13	0.9	0.3	12
12 "	4.7	0.8	0.3	17	1.5	0.5	15
13 "	5.3	0.7	0.4	13	0.8	0.4	11
14 "	5.3	1.6	0.7	13	2.2	0.9	13
15 "	5.3	0.8	0.3	15	1.2	0.5	13
16 "	4.2	1.4	0.5	19	2.0	1.0	13
17 "	6.1	0.6	0.3	12	0.9	0.5	9
18 "	6.9	1.6	0.3	12	0.6	0.3	12
19 "	4.2	2.5	0.9	12	3.1	1.6	10
20 "	5.0	1.0	0.3	11	0.9	0.5	7
21 "	6.1	0.8	0.2	13	0.9	0.3	10
22 "	2.2	1.9	1.0	10	2.6	1.5	9
23 "	4.7	2.1	0.5	12	2.6	0.7	9
24 "	6.1	0.6	0.2	12	1.2	0.3	8
25 "	5.3	0.8	0.3	10	0.6	0.4	8
26 "	6.7	0.3	0.1	12	0.4	0.2	8
27 "	5.3	0.3	0.1	13	0.1	0.1	11
28 "	5.8	0.0	0.0	14	0.1	0.1	5
29 "	7.2	0.2	0.0+	11	0.1	0.1	6
30 "	5.5	1.9	0.4	10	2.0	0.7	6
31 "	7.5	0.9	0.4	10	0.9	0.5	10

Table 1b

Inversions in 1984 (14 April to 27 May)

Night ending	'Minimum' Temperature	Inversions 10 m Max	10 m Mean	10 m Hours	15 m Max	15 m Mean	15 m Hours
15 Apr	3.8	3.8	1.4	13	4.6	1.8	12
16 "	0.4	3.0	0.8	11	3.2	1.0	11
17 "	-0.6	3.4	1.5	12	4.2	1.8	12
18 "	2.4	2.0	0.7	12	2.2	0.8	12
19 "	7.6	1.4	0.4	12	1.8	0.5	12
20 "	6.0	1.6	0.9	13	2.0	1.1	13
21 "	4.2	3.6	2.2	12	4.4	2.8	12
22 "	7.6	5.4	2.2	13	6.2	2.9	12
23 "	3.0	0.8	0.4	8	1.0	0.4	9
24 "	0.8	2.2	1.1	11	3.0	1.4	11
25 "	4.0	2.4	1.2	11	3.2	1.4	11
26 "	0.2	3.8	1.7	11	4.6	2.3	11
28 "	-0.8	4.0	2.0	11	4.6	2.8	11
29 "	0.0	3.0	1.4	11	3.6	1.8	11
30 "	-1.6	4.8	2.1	11	5.6	2.7	11
1 May	3.8	2.0	1.2	10	2.4	1.5	11
2 "	6.6	0.4	0.2	2	0.4	0.2	2
3 "	7.0	0.8	0.4	2	0.8	0.4	2
5 "	5.6	1.4	0.8	2	1.6	0.9	2
7 "	4.4	0.4	0.1	10	0.4	0.1	7
8 "	3.4	1.0	0.3	9	1.0	0.3	8
		Missing data 8-11th					
12 "	4.6	1.0	0.6	10	1.4	0.8	10
13 "	2.6	1.8	0.8	10	2.2	1.0	10
14 "	1.4	2.6	1.3	10	3.2	1.8	10
15 "	1.8	2.8	1.8	10	4.0	2.3	11
16 "	7.4	0.4	-	-	0.4	-	-
18 "	5.0	1.0	0.5	5	1.6	0.7	5
19 "	1.6	3.6	1.3	6	4.4	1.7	6
20 "	0.4	3.8	2.1	7	5.2	2.6	8
23 "	4.4	1.8	0.7	9	2.2	0.9	8
24 "	8.4	0.4	0.3	5	0.4	0.4	2
27 "	6.0	0.2	0.0	-	-	-	-

Table 2

Summary of inversions

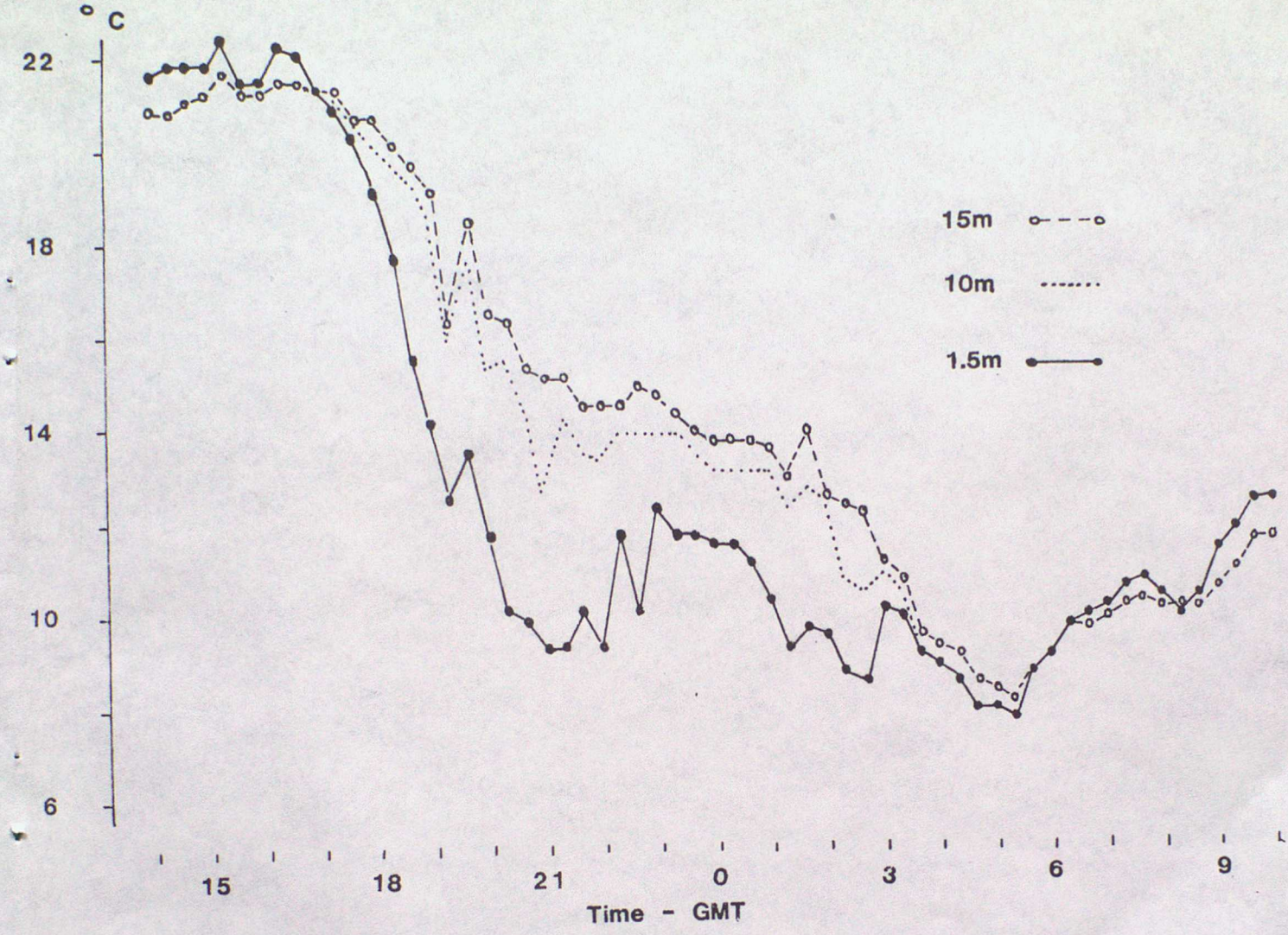
	10 m		15 m	
	1983	1984	1983	1984
Maximum inversion				
highest	2.5	5.4	3.1	6.2
mean	1.0	2.2	1.1	2.8
lowest	0.0	0.2	0.1	0.4
Mean inversion				
highest	1.0	2.2	1.6	2.9
mean	0.4	1.0	0.5	1.4
lowest	0.0	0.0	0.0	0.1

Table 3

Circulation types in April and May

	Cyclonic	Anticyclonic	Other
1983			
April	18	3	9
May	18	2	11
1984			
April	3	22	5
May	6	14	11
1962-71 Average			
April	6.6	8.6	14.8
May	8.0	8.9	14.1

Temperatures at Fransham 21-22 April 1984



Development of Inversion Profile

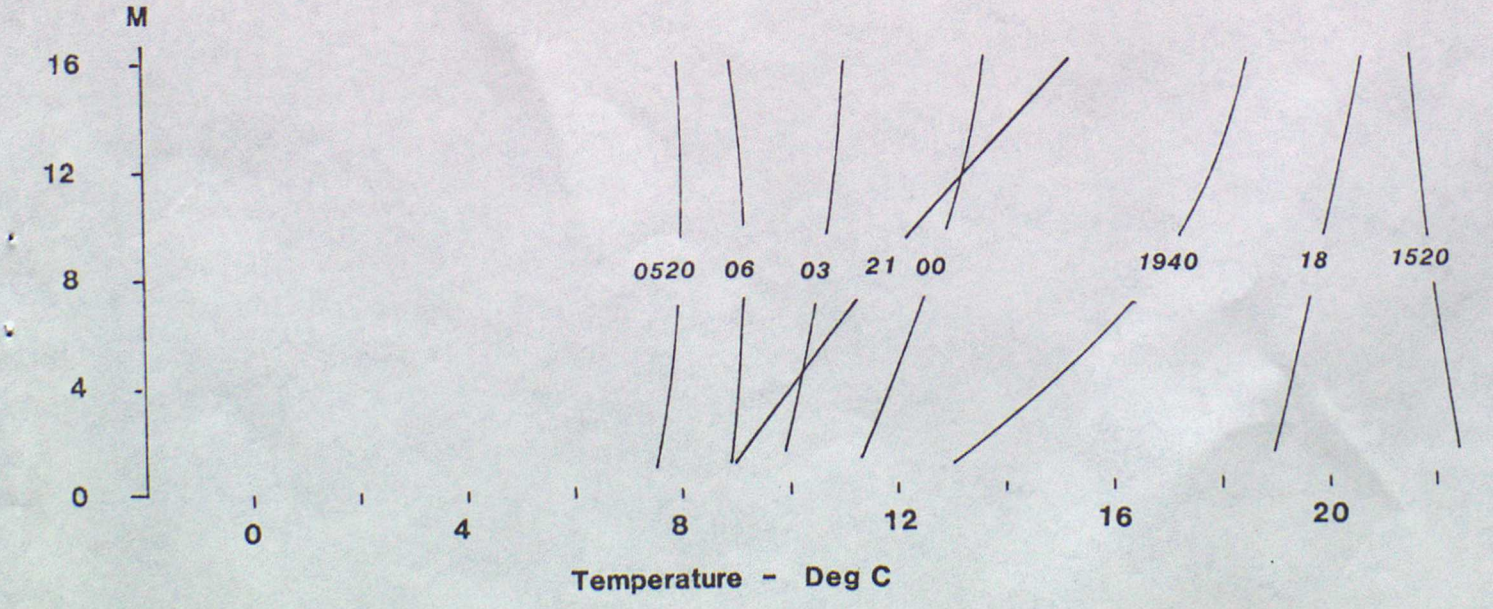
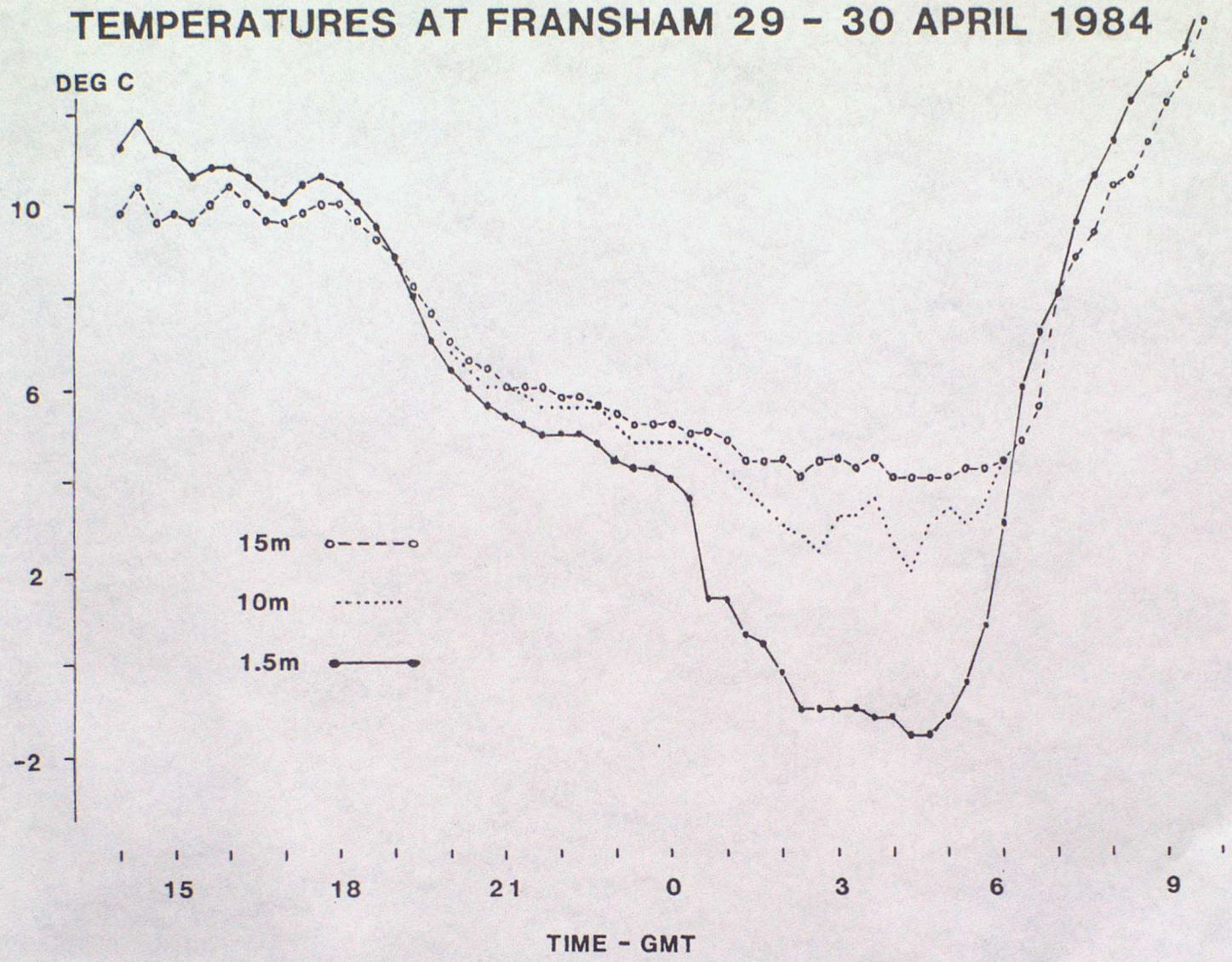


Figure 1


TEMPERATURES AT FRANSHAM 29 - 30 APRIL 1984
DEG C
10
6
2
-2
15m
10m
1.5m
15
18
21
0
3
6
9
TIME - GMT

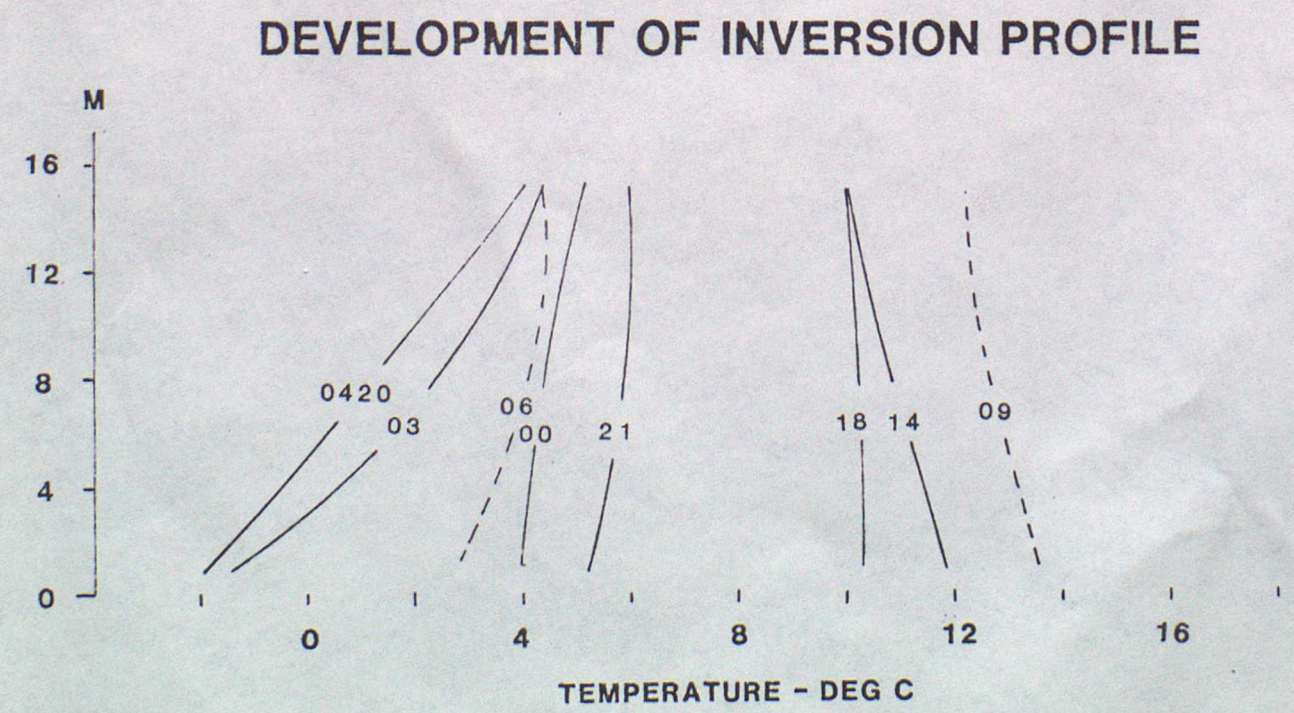
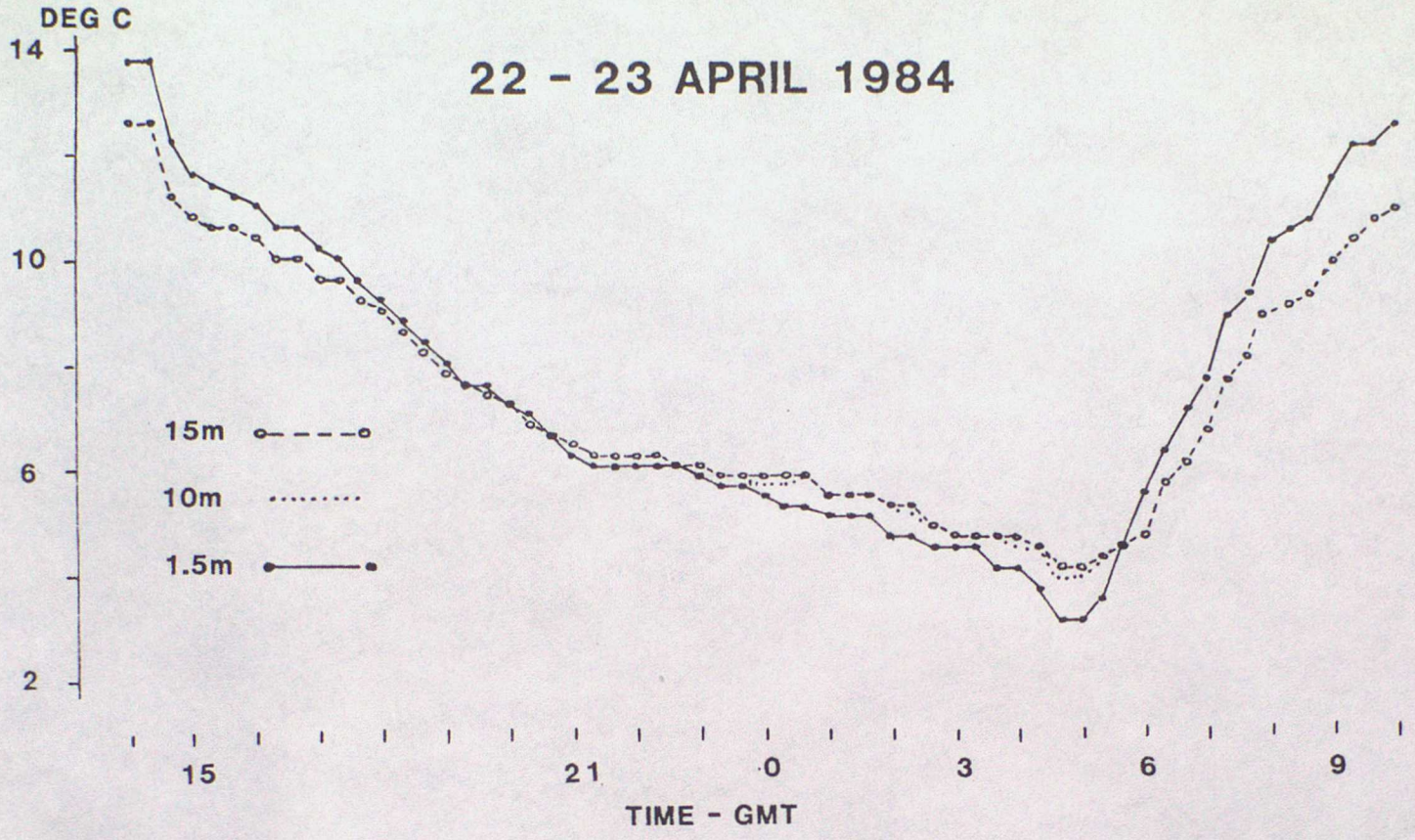

DEVELOPMENT OF INVERSION PROFILE
M
16
12
8
4
0
0420
03
06
00
21
18
14
09
0
4
8
12
16
TEMPERATURE - DEG C

Figure 2

TEMPERATURES AT FRANSHAM



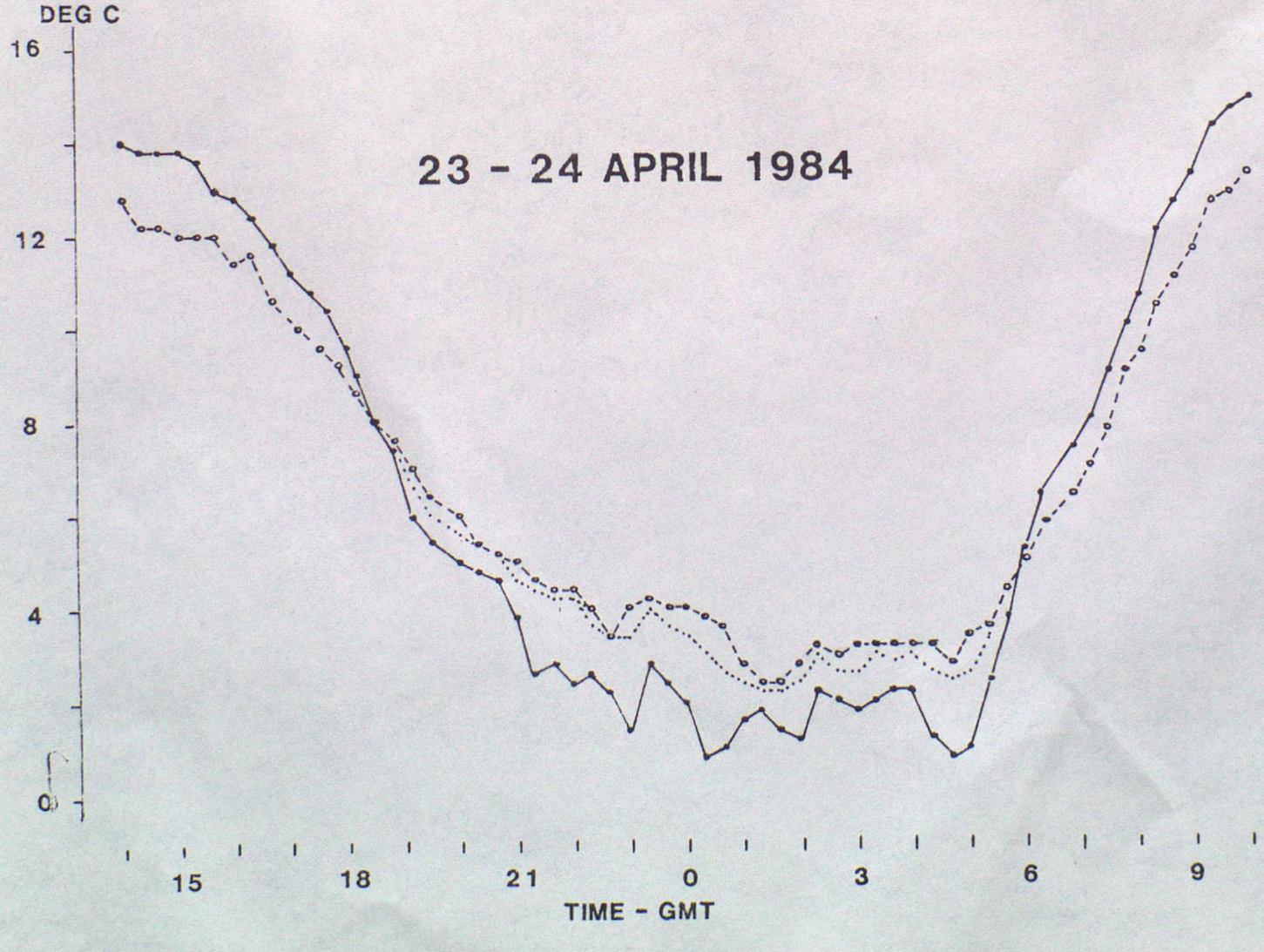


Figure 3